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Ionospheric Modeling: Development, Verification and Validation

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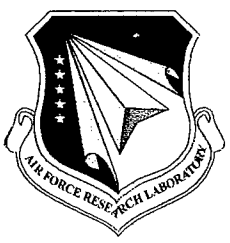

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14. ABSTRACT
Much of the work performed this year has been directly related to the validation of the Global Assimilation of Ionospheric Measurements (GAIM) model. Summaries of these efforts are in 26 reports available within the Air Force Research Laboratory (AFRL) on http://dd175/gaim/. Studies were also initiated to enhance the development of high-quality GPS data products and to validate the ability of the Special Sensor Ultraviolet Spectrographic Imager (SSUSI) onboard the Defense Meteorological Satellite Program (DMSP) F16 satellite to measure Total Electron Content. Finally, efforts were expended to evaluate historical data sets for future activities in support of ionosphere effects on Space Situational Awareness (SSA), flight experiments and surveillance system programs.

15. SUBJECT TERMS
Ionosphere, Specification, Forecasting, GAIM,TEC, SSUSI, Space Situational Awareness

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Air Force Contract FA8717-04-C-0055

Period Ending: July 2005

1. GOALS, PROGRESS and TECHNICAL PLANS

The objectives of this contract are to improve specification and forecast models currently in use and in development at AFRL. These efforts include performing independent research to augment AFRL's programs in the areas of direct simulation Monte Carlo modeling of chemical releases, Geospace plasma dynamics, and in modeling studies for the purpose of driving and validating the theoretical models and applications that are the basis of the Parameterized Real-time Ionospheric Specification Model (PRISM) and the Ionospheric Forecast Model. Other recent efforts have included reviewing legacy data to determine the pertinence of these data sets in space situational awareness studies.

2. GAIM VALIDATIONS

Much of the work performed in the first year of this contract has been related to the validation of the Global Assimilation of Ionospheric Measurements (GAIM) model. A few years ago, the Department of Defense (DoD) funded a Multi-Disciplinary University Research Initiative (MURI) to develop a global, ionospheric data assimilation model. This funding represents the first time a concerted effort has been made to develop a space weather global ionospheric model similar to the numerical weather models that were initiated more than forty years ago. Two versions of the Global Assimilation of Ionospheric Measurements (GAIM) model were developed. The version of the model that we have been validating was initiated by Utah State University. In the first year of this contract, nearly 30 studies have been initiated. The following reports were written describing the research and conclusions of these efforts. Full reports of the research are available from within AFRL, at http://dd175/gaim/.

1. *Studying the IRIS Effect using Quasi-Parabolic Ionospheric Layers* (July 2004)
2. *Establishing Error Bars for Plasma Frequency Profiles Derived from Vertical Incidence Ionograms* (August 2004)
3. *Plasma Frequency Error Bars as a Function of Altitude for Profiles Deduced from ARTIST Autoscaled Ionograms* (August 2004)
4. *Procedures for Identifying Physically Unreasonable N(h) profiles of the Ionosphere Generated by PRISM* (September, 2004)
5. *Procedures for Identifying Physically Unreasonable N(h) profiles of the Ionosphere Generated by PRISM* (September, 2004).
6. *Validating the GAIM N(h) Profiles at an Equatorial Location* (September, 2004)
7. *Validating the GAIM Sub-Peak Plasma Frequency Profiles at Australian Sites* (September, 2004)

8. *Comparison of GAIM and CHAMP Plasma Frequencies* (October, 2004)
9. *Sanity Checking of GAIM Plasma Frequency Profiles* (November 2004)
10. *QualScan – A Fortran Program for post-processing autoscaled ionograms* (December 2004)
11. *Sanity Checking if GAIM and PRISM Plasma Frequency Profiles for 2002/150-152* (January 2005)
12. *Sanity Checking of PRISM Plasma Frequency Profiles* (March 2005)
13. *Inter-comparison of CLM, RTA, IFM, GMF and Ionosonde Plasma Frequency Profiles for March-April 2004* (March 2005)
14. *Comparison of PRISM, GAIM and TOPEX Total Electron Content* (March 2005)
15. *Comparison of PRISM and CHAMP Plasma Frequencies* (March 2005)
16. *Comparison of GAIM Values of TOPEX TEC, CHAMP Plasma Frequency and Ionosonde foF2 for Example Intervals 1, 2 & 3* (April 2005)
17. *Comparison of IFM, BAK and GMF Predicted Values of TOPEX TEC, GAIM Plasma Frequency, and Ionosonde foF2* (April 2005)
18. *Comparison of ARTIST and POLAN Plasma Frequency Profiles for Autoscaled Ionograms* (April 2005)
19. *Quality Figures and Error Bars for Autoscaled Vertical Incidence Ionograms* (May 2005)
20. *Comparison of GAIM and QualScan plasma frequency error bars for sub-peak profiles. (May 2005)*
21. *Comparison of PRISM and Observed Values of TOPEX TEC, CHAMP Plasma Frequency and Ionosonde foF2 for Example Intervals 1, 2 & 3* (May 2005)
22. *Outlier Errors in the GAIM Values of TOPEX TEC* (July 2005)
23. *GAIM Error Bars for Ionograms not Processed by POLAN* (July 2005)
24. *Effects of Different Types of Real-Time Data on GAIM and PRISM Accuracies for Three Days in March 2004* (July 2005)
25. *Effective Sunspot Numbers for TEC Calculations using the RIBG Program* (July 2005)
26. *Comparison of CHAMP and Digisonde Plasma Frequencies at Jicamarca, Peru* (July 2005)

3. IONOSPHERIC SENSING WITH GPS

Studies were initiated this year to support the continued development of high-quality GPS analysis techniques. In this effort, a series of 10 worldwide locations representative of low, mid and high latitude ionospheric conditions were used to define the problems of TEC processing for different regions of the world. Several groups were invited to compare processing techniques in the effort to quantify the benefits of different processing algorithms. The results of the workshop identified the need to refine and agree on methods to determine the absolute values of GPS receiver offsets.

This topic is vital to the quality control of GPS data sets used as input to GAIM assimilation models. It is also important to refine an algorithm to facilitate the automated processing of a large network of GPS receiver data.

4. CALIBRATION AND VALIDATION OF IONOSPHERIC SENSORS

We have been supporting AFRL/VSBX in the performance of a validation study of the Total Electron Content (TEC) derived from nighttime limb scan observations made by the Special Sensor Ultraviolet Spectrographic Imager (SSUSI) onboard the Defense Meteorological Satellite Program (DMSP) F16 satellite.

The basic idea of this study was to use the vertical TEC deduced from the JASON dual-frequency radar altimeter as ground truth data for comparison with the SSUSI inferred TEC. The TEC from the JASON satellite is derived from a dual-frequency altimeter designed for ocean dynamics investigations. As a result, the TEC observations are available only when the satellite is over water. Thus, the first step of this work involved identifying coincidences between the JASON satellite and DMSP F16 satellite that occur over the water. Once coincidences are identified, data from both satellites are processed and comparisons between the two TEC sources are performed.

At the completion of the first year of this contract, much of this work was completed. In particular, software was developed and performed to define the coincidences between JASON and the DMSP F16 satellite. Further software was developed and performed to determine the optimal method to process and utilize the SSUSI measurements that were received from APL and Aerospace Corporation. Additional efforts were applied to make the first comparisons between JASON TEC and SSUSI TEC. The first results were promising in that SSUSI appeared to capture the larger features of the equatorial anomaly. In particular, early results showed that SSUSI TEC placed the equatorial peak close in latitude to that defined by JASON. The problems appear to be the inability of SSUSI to capture the depth of the equatorial trough.

Periodic updates of the progress of this effort were reported at CAL/VAL meetings held at the Applied Physics Laboratory at Johns Hopkins in Laurel, Maryland. At the time of this writing, algorithm corrections were being made for the SSUSI data sets that were being supplied by both APL and the Aerospace Corporation. Further work will identify the comparisons of the entire data set. At the completion of this effort, a final report will be written that describes the software and algorithm development and the statistical summary of the results.

5. PRESENTATIONS

P.H. Doherty, Benefits of C/NOFS on Studies Related to the Ionospheric Impacts on Navigation, C/NOFS Workshop, Estes Park, CO, January 2005.

L. F. McNamara, Specifying Error Bars for Profiles Derived from Ionograms, presented at the URSI Radio Science Meeting, Boulder, CO, January 2005.

L.F. McNamara, Monitoring Equatorial Bubbles using VHF Transequatorial Propagation, C/NOFS Workshop, Estes Park, CO, January 2005.

W. Rideout, A. Coster, **P. Doherty**, MIT Haystack Automated Processing of GPS Data to Produce Worldwide TEC Maps, presented at the URSI Radio Science Meeting, Boulder, CO, January 2005.

L. F. McNamara, Richard J. Barton, and Terence W. Bullett Collection and Analysis of HF Radio Signal Observations on Two North American Circuits, Paper 2- Data Analysis, presented at IES2005, Alexandria, VA, May 2005.

D. T. Decker, **P.H. Doherty**, SSUSI Calibration and Validation of TEC from the DMSP/SSUSI Instrument, presented at a series of CAL/VAL meetings hosted at APL-Johns Hopkins, Laurel, Maryland, 2004-2005.

6. PAPERS

Su. Basu, S. Basu, J.J. Makela, R.E. Sheehan, E. MacKenzie, **P. Doherty**, J.W. Wright, M.J Keskinen, D. Pallamraju, L.J. Paxton and F.T. Berkey, **Two components of ionospheric plasma structuring at midlatitudes observed during the large magnetic storm of October 30, 2003**, *Geophysical Research Letters,* Vol. 32, L12S06, doi:10.1029/2004GL021669, 2005.

Abstract
We consider VHF amplitude scintillations, GPS phase fluctuations, ionosonde measurements, maps of GPS total electron content (TEC), observations of daytime aurora and TIMED GUVI images during the large magnetic storms of October 29-31, 2003, and find two distinct classes of plasma processed that produce midlatitude ionospheric irregularities. One is associated with auroral plasma processes; the other, with storm enhanced density (SED) gradients, a part of which occur in close proximity to sub-auroral polarization stream (SAPS) electric fields as discussed by J.C. Foster et al. (2002). We analyze in detail the storm event of October 30, 2003. The SAPS-associated plasma structures may occur by an ion temperature gradient convective instability (M.J. Keskinen et al., 2004), but structuring by auroral processes requires elucidation.

L.F. McNamara, R.J. Barton and T.W. Bullett, **Analysis of HF Signal Power Observations on Two North American Circuits**, submitted to *Radio Science*, July 2005.

Abstract

Observations of HF signal powers on two circuits in North America have been compared with the values predicted by two HF propagation programs, VOACAP and ASAPS. Neither program consistently provided the more reliable predicted signal powers. For the longer circuit considered (2820 km WWV Fort Collins to Hanscom AFB), ASAPS was found to be the more accurate program for the lower frequencies (at night), while VOACAP was the more accurate for the higher frequencies (during the day). The RMS errors ranged from a few dB to 15 dB. For daytime 7.335 MHz propagation on the 490 km CHU Ottawa to Hanscom AFB circuit, the VOACAP RMS errors (~4 dB) were less than the ASAPS RMS errors (~8 dB). The errors for the two programs were very similar for 3.330 MHz propagation, peaking at ~9 dB just after sunrise and just before sunset, and ~3 dB during the night. Index Terms: 2443 Midlatitude ionosphere, 2447 Modeling and forecasting, 2494 Instruments and techniques.